Radial Density Profile Measurement at Different RF Power in Argon Plasma Using RF Compensated Langmuir Probe

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Abstract: Langmuir probe is a powerful diagnostic tool for low pressure gas discharge plasmas, the ability of measurement of local plasma parameters and the electron energy distribution function (EEDF) makes it unique among other diagnostics. The Langmuir probe is consisting of small wire put in contact with the plasma thus measuring the current from the plasma at various applied voltages. We have fabricated Langmuir probe for the characterisation of RF produced plasma at SVITS, with calculated value of capacitor and inductor for the first and second Harmonics of frequency 13.56 MHz. A system has been designed, fabricated and installed at SVITS, Indore for producing tungsten coatings using Plasma Enhanced Chemical Vapor Deposition (PE-CVD) methodology. Variation of electron density with radial distance inside the plasma along the diameter of electrode ofRF Glow Discharge Argon Plasma will be discussed in this paper

1. INTRODUCTION

Variation of density with radial distance provides the effective uniform area for any coating process for plasma enchanted chemical vapour deposition (PECVD) method. Especially, in RF plasmas accurate measurement of density and potential require exact probe compensation otherwise the high frequency interferes the measurements. The purpose of the present development is tracing a uniform area for coating of tungsten in a coating reactor with PECVD. We have constructed a compensated Langmuir probe to measure and estimate the electron temperature (T_e), electron density (n_e), and electric potential (V_p) of RF assisted plasma. It works by inserting a small metallic pin electrode into the plasma, with applying a constant or variable (RAMP) biasing potential across the probe and the surrounding grounded vessel. The currents and potentials from the plasma are measured in plasma system allows us determining the plasma parameters. In the initial stage of experimentation, Argon plasma is produced in the coating reactor to identify the spatial region with optimum uniform plasma parameter for coating by measuring plasma electron density and temperature. The vacuum chamber is evacuated to a base pressure up to ~ 2 x 10^{-6} mbar using a turbo-rotary combination of pumping system, the Argon gas is inserted at ~ 1.1 x 10^{-3} mbar pressure into the chamber for experiments. The electrodes are circular and the distance between the top and bottom electrodes are kept at ~ 6cm and the plasma is produced by varying the RF power from 10 W to 300 W with an auto matching network ensuring minimum reflected power. Plasma parameters are measured with a RF compensated Langmuir probe at different RF powers inserted from the radial port (13.56 MHz). The plasma is initiated at ~ 60W of RF power and the density of the plasma increases as the RF power is increased up to 300W in the reactor chamber. Excellent RF coupling is observed between the electrodes i.e. anode and cathode in our experimental system with almost no (zero) power reflection up to 300W plasma operation using the auto matching network.

2. EXPERIMENTAL SETUP

A system has been designed, fabricated and installed at SVITS, Indore for radial density profile measurement at different RF power in Argon Plasma using Langmuir Probe by the Plasma Enhanced Chemical Vapor Deposition (PE-CVD) technique for Fusion plasma applications. Fig. 1 is the block diagram of the experimental arrangement at SVITS coating system consisting of a vacuum chamber, a stainless-steel target (cathode) and anode disk. The cathode and anode are parallel faced that provide the necessary electric field for the gas to breakdown and strike plasma discharge. The substrate is biased with a DC-power supply of 2 kV, 1 Amp. The top electrode is anode while bottom electrode is targeting electrode and the gap distance between them is variable upto 10 cm. The Diagnostics ports around the reactor system are 35 CF & 63 CF**.** The plasma chamber is having a height of 30cm, and diameter 36cm, and equipped with pirani, penning and cold cathode pirani gauges. The RF power supply (13.56MHz) is capable of producing a plasma up to 600Watt, ammeter for discharge current measurements, Argon (for test all the sub-systems), N2 and H2 gas source, Langmuir probes made of tungsten wire with its surface covered by ceramic bushing is inserted from the radial port of the chamber with RF filter incorporated to it. The gas flow to the reactor chamber is controlled by mass flow controllers (0-200 sccm), the gas composition is monitored with a residual gas analyzer (RGA, 300 amu), and four channel Oscilloscope is employed for electrical diagnostics measurements.

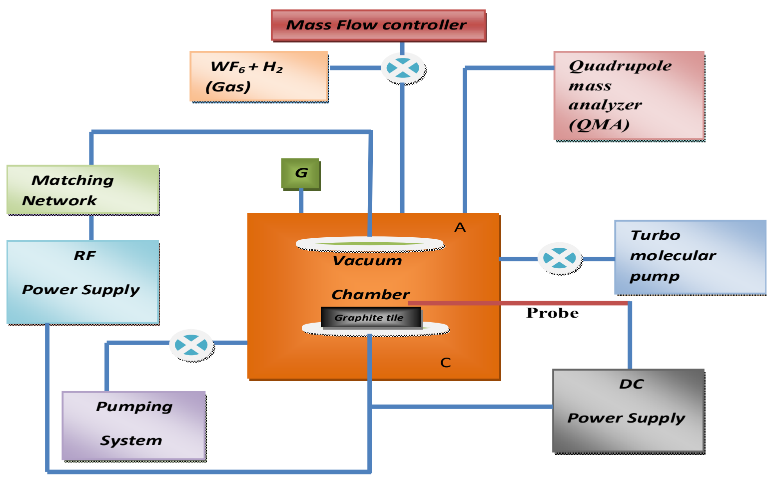

Figure 1 – Block diagram of coating reactor and associated accessories at SVITS.

3. LANGMUIR PROBE

A Langmuir Probe has been designed, fabricated and installed at SVITS. The most straight forward way to measure the radial density of plasma is by biasing the probe to a fixed negative bias voltage and collect the ion saturation current. And a second probe ramped between -80V to +30V thus collecting the probe characteristics and estimating the electron temperature. The advantages are simplicity of the electrode and the information embedded in the probe I-V characteristics, i.e. one can in principle estimate the radial density, electron energy distribution function, plasma floating potential, plasma potential and electron temperature etc.. Argon gas neutral pressure is maintained by MFC during the experiments.

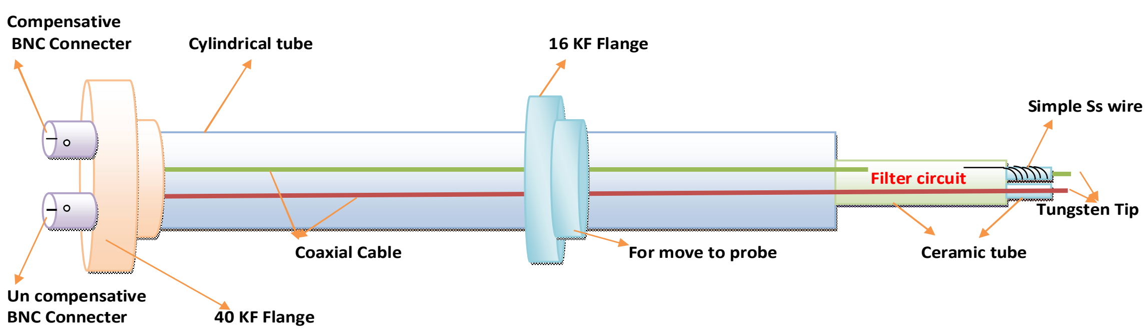

Figure 2 - Schematic of the Langmuir probe used in the system.

The schematic of the RF compensated Langmuir probe is shown schematically in Fig.2. The tip of the probe is made of Tungsten wire diameter of 0.1mm and length 10mm exposed to the plasma for measurement. A passive RF filter compensating the 13.56 MHz is connected to the tip of the Langmuir probe with values of capacitance and inductance suits the compensation within 5% of the error respectively such that frequency of 13.58 MHz resonates to the high impedance. This arrangement aiming to suppress the interference in the measured radial density signals. The current is monitored as a differential voltage across a 0-10 k Ω resistor. The schematic diagram of the probe electronics arrangement is shown in the Fig. 3. A low pass filter is connected at the input of the measurement system in order to eliminate the RF noise which supposedly picked by the signal cables.

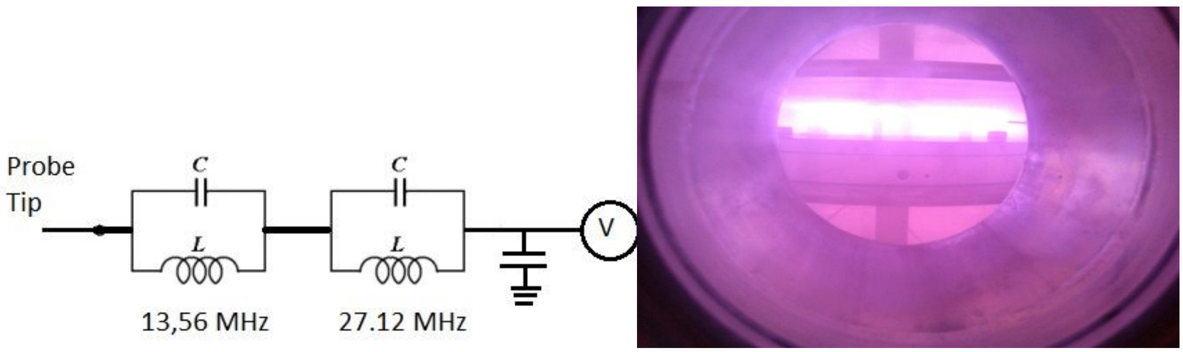

Figure 3. Schematic circuit design of RF compensated Langmuir probe for 13.56MHz and its second harmonic and produced Argon RF plasma in SVITS coating reactor.

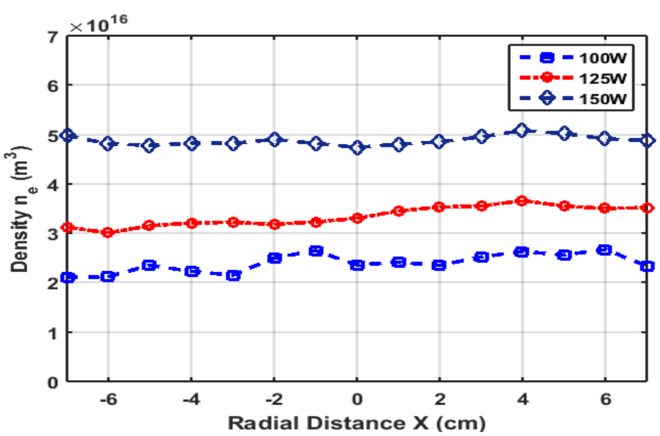

Figure 4 Radial density profile measured at different RF power 3cm above the bottom electrode.

4. RESULTS AND DISCUSSION

At Argon neutral gas pressure of 4.0 x 10^{-4} mbar with RF power varied in the range of 100W-150W, plasma density ~ 2 x 10^{16} m^{-3} – 5.1 x 10^{16} m^{-3} and temperature ~ 1.0eV - 1.5eV (spectroscopic measurement) have been obtained at 3 cm above the bottom electrode on the axis of the electrodes. This range of density and low electron temperature is quite suitable for performing the coating experiments. Figure 4 shows the radial plasma electron density profile at different RF power 3cm above the bottom electrode on which the samples are to be placed for tungsten coating experiments. It has been observed that the plasma is uniform over the radial extent of ±7 cm from the centre covering the complete radial extent of the bottom electrode. The region is identified so that the substrates can be placed in this uniform region so that they are exposed to homogeneous plasma thus uniform coating on the substrate can be obtained. Similar measurements of radial profiles of density have been carried out in hydrogen plasma to ascertain the area of uniform coating before actual coating experiments are carried out for radial density profile uniformity.

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